National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

Reply to Attn of: 970

November 18, 1994

TO: Distribution

FROM: 970/Associate Chief, Laboratory for Hydrospheric Processes

SUBJECT: Deviation Request for MODIS VIS/NIR Bands

Enclosed are the results of analysis conducted by Ed Knight to determine the impact of deviations requested by SBRC on the spectral performance specifications of 8 bands in the Visible/NIR InfraRed (VIS/NIR) of Moderate Resolution Imaging Spectroradiometer (MODIS). As noted, several of these deviations were addressed previously and found acceptable. Ed has conducted a thorough examination of each proposed deviation and has, in one case, determined the impact of the changes on a science product (Fluorescence Line Height).

Ed has concluded that the requested deviations are acceptable with some minor adjustments as shown in Table 6. I concur with Ed's recommendations and will be sending a memorandum to that effect to the MODIS Instrument Systems Manager in the near future. In the meantime, I would like for you to examine Ed's results and offer any comments.

It is worth noting that this should conclude any changes in the spectral response of the VIS/NIR bands (hopefully for all flight models since the plan is to use additional pieces from the same bandpass filters). However, there may be a similar set of minor adjustments to the MidWave InfraRed/ShortWave InfraRed (MWIR/SWIR), and LongWave InfraRed (LWIR) specifications after their measurements are complete.

WL Barnes
William L. Barnes

Enclosure

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November 18, 1994

TO: 970/Bill Barnes/MODIS Instrument Scientist
925/John Barker/MCST Calibration Scientist

FROM: 925/Edward Knight/MCST/RDC

SUBJECT: SBRC's Deviation Wavier Request for VIS/NIR Bands

REFERENCES:

1. "VIS, NIR Spectral Performance Model for PF," PL3095-M04247, T. Pagano, Sept. 22, 1994.

2. "SBRC's Request for a Deviation on Band 19 Center Wavelength," memo from W. Barnes, J. Barker, E. Knight to R. Weber, March 7, 1994.

3. "Spectral Response of Band 11," memo from W. Barnes to K. Anderson, July 7, 1994.

4. "Waiver for Band 9," memo from W. Barnes to K. Anderson, July 13, 1994.

5. "Band 9 Deviation Request," memo from E. Knight to W. Barnes et al, August 2, 1994.

6. Chlorophyll Fluorescence (MODIS Product Number 21) Algorithm Theoretical Basis Document, Mark R. Abbot, 1994.

Summary

On October 4, 1994, SBRC submitted a deviation waiver for the spectral characteristics of several spectral bands. These waivers cover center wavelength (Bands 14 and 19), Bandwidth (Band 11), and Edge Range (Bands 8, 9, 13, 14, 15, 18). The referenced memos examined three of these nine deviations and found them to be acceptable. This memo examines the remaining six cases. A summary of my recommended acceptable deviations for all nine bands is presented in the conclusion.

Background

This summer SBRC selected the filters for use on the Proto-Flight Model. Previously SBRC has measured the spectral response of the optical components and of the detectors. Using an SBRC algorithm independently confirmed by GSFC, it is possible to convolve the component results and predict the system level response. This study refers to this calculated result as the "expected performance." The performance for the specification filter is referred to as the "nominal performance." From these predictions, SBRC and I have been able to make system level spectral response predictions that indicate specification non-compliance for 8 bands in the Visible and Near-Infrared Focal Planes. SBRC has requested a waiver on the center wavelength for bands 14 (0.3 nm beyond tolerance) and 19 (5 nm beyond tolerance), the bandwidth for band 11 (0.1 nm beyond tolerance), and edge ranges for bands 8, 9, 13, 14, 15, and 18 (from 0.1 to 1.8 nm beyond tolerance). With consultations from John Barker, I have examined each of these cases for this report.

One caveat is that the results in this report may vary slightly from those seen for individual detectors within a band. For each filter, SBRC measured the spectral profile at 5 locations. The measurement uncertainty is $\pm$ 0.2 nm and variations between the five spots were consistently within this accuracy. To calculate the system level results, SBRC consistently used the first spot (at the top of the filter, where detectors 1 and 2 would be). Neither SBRC nor I attempted to generate an "average response." The results presented here for bands 8, 13, 14 and 15 are based on the "worst spot" for that given filter. Due to the measurement uncertainty, these are all considered equivalent. I have chosen the worst case to ensure that all spots, as currently predicted, meet the accepted specification value.

Also note that this analysis does not address the out-of-band response.

Analysis

I will discuss each band individually and then provide a discussion of the impact of Bands 13, 14, and 15 on the Chlorophyll Fluorescence Product.

Band 8

Band 8 is an ocean color band centered at 412 nm, which is the shortest wavelength band in MODIS. Figure 1 shows the nominal system performance (or specification performance) and the expected performance superimposed on the solar spectra. Figure 2 shows this system level response and the nominal response superimposed on a top-of-atmosphere spectrum over oceans generated by the MCST models. As can be seen from Figures 1 and 2, Band 8 continues to avoid the absorption features at ~390 and ~435 nm. It still evenly straddles the Fraunhofer line at 410 nm. Table 1 gives a summary of the relevant spectral characteristics.

SBRC has requested a deviation waiver for the lower edge range (the distance between the 5% and 80% response points) of 8.8 nm, which is 1.4 nm beyond specification. This is based on the protoflight measurements of the optics and filters. Since the coatings and lenses on the protoflight model have been modified to fix ghosting, these vary from the engineering model. For most bands, this does not affect the spectral profile, only the overall transmission (and scatter). However, Band 8 is located where the dichroics and optics begin to cut off, and is strongly influenced by these differences. Specifically, in addition to separating the thermal and reflective bands, Dichroic One blocks the wavelengths below ~400 nm. Figure 3 contrasts the PFM and EM performance and shows how both edges are reduced from the filter component response. Table 1 contains the characteristics for both models. As can be seen, the EM lower edge range is a full 1.0 nm larger (9.8 nm, or 2.4 nm beyond specification) than the PFM lower edge range. This memo concentrates on the PFM results for waiver purposes, but these results indicate that we should expect differences in the Band 8 response between EM and PFM.

The total integrated signal for the expected performance (as determined by the integrated radiances in Table 1) is 11% lower than the nominal filter. Note that SBRC has already accounted for much of this in their SNR budget (the nominal filter here is assumed to have a peak transmittance of 1.00, whereas in calculating SNR, SBRC assumed .83 peak transmittance). The SNR is reduced less than 1% from previous SBRC predictions.

With Robert Mahoney's (of RPS) assistance, I have examined the shift sensitivity for band 8 with respect to both the Solar spectrum and the TOA spectrum. Figures 4 and 5 present these results. These results indicate little change in the shift sensitivity between the nominal and expected performance for band 8.

My conclusion is therefore that while Band 8 is ugly, the net effect of the edge range difference is mainly a reduction in the total signal. Since this does not affect the SNR by more than 1% and we have a margin of 25%, I believe this is acceptable.

Band 9

References 4 and 5 examined the lower edge range for band 9, which was 7.3 nm (1.8 nm beyond specification). That analysis concluded that the filter was acceptable. Reference 4 misquotes this edge range as 7.2 nm. An upper edge range deviation of 6.8 nm was not included in the conclusion of references 5 by mistake. The same analysis used for those references also indicates that the upper edge range deviation of 6.8 nm is acceptable.

There are no measurable differences between the current as-built data and the data used in references 4 and 5. On the basis of the analysis in references 4 and 5, I believe the lower edge range deviation of 7.3 nm (1.8 nm beyond specification) and the upper edge range deviation of 6.8 nm (1.3 nm beyond specification) are acceptable.

Band 11

There are no measurable differences between the current data and the data used in reference 3. Based on reference 3, the bandwidth deviation of +2.0 nm (0.1 nm beyond tolerance) is acceptable.

Band 13

Band 13 is one of three bands (with Bands 14 and 15) used to detect ocean chlorophyll. Specifically, Bands 13 and 14 are used to measured the fluorescence of phytoplankton near 683 nm. Figure 6 shows the nominal and expected system level performance of Band 13 imposed on the ocean surface spectra for two different chlorophyll levels. Figure 7 superimposes these responses against the solar spectrum and Table 2 summarizes Band 13's spectral characteristics. Top of Atmosphere spectra were examined for Band 13 and 14, but are not included here as they tend to obscure the chlorophyll peak and do not add any significant structure. Thus I am essentially assuming that the Oceans Community can do a perfect atmospheric correction.

For Band 13, SBRC has requested a deviation waiver for the upper edge range of 6.1 nm, which is 1.05 nm beyond specification. Originally there was an additional concern that the overall transmittance was lower than expected. This turned out to not be the case. Band 13's SNR is still more than 40% above specification. Figure 7 shows that Band 13 does not overlay the Fraunhofer line at about 657 nm.

Again, Robert Mahoney and I examined the shift sensitivity. We used the 10 mg/m^3 Chlorophyll Oceans Surface spectrum and the Kurucz Solar Spectrum. Against the oceans spectrum (Figure 8), there is little difference between the nominal and expected performance. Against the solar spectrum (Figure 9), one can see that the expected performance will be sensitive to the 657 nm Fraunhofer line sooner than the nominal case. However, the net effect is to make the magnitude of the change in the signal smaller than the nominal case until we have undergone a -5 nm shift. With the SRCA resolution of 1.0-1.5 nm (predicted-spec.) at this band, such a large change should be detectable. I believe we can tolerate the slightly larger shift sensitivity.

The deviations in Band 13 will have an impact on the chlorophyll fluorescence product (Fluorescence Line Height, or FLH). This will be discussed in a subsequent section.

Since the variation in the shift sensitivity is tolerable, the edge range does not extend the spectral response into any strong solar spectra, the SNR is still adequate and the impact on the FLH product is minimal (see subsequent section), I believe that the upper edge range deviation is acceptable.

Band 14

Band 14 is the central band used to detect ocean chlorophyll by measuring the fluorescence of phytoplankton near 683 nm. Figure 10 shows the nominal and expected system level performance of Band 14 imposed on the same ocean spectrum used for Band 13. Figure 11 superimposes these responses against the solar spectrum and Table 3 summarizes Band 14's characteristics.

Band 14 has two requirements that are out of specification. The center wavelength is 1.3 nm low (676.7 nm), which is 0.3 nm below tolerance. Additionally, the lower edge range is 5.8 nm, which is 0.1 nm beyond specification (5.7 nm). The signal to noise ratio remains high. The effect of the center wavelength shift and long lower edge range is to slide Band 14 slightly down the Chlorophyll emission peak (Figure 10).

The shift sensitivity against the 10 mg/m^3 Chlorophyll Oceans Surface spectrum and against the solar spectrum are presented in Figures 12 and 13.

They show differences from the nominal performance only for large positive shifts against the ocean surface spectrum. At these wavelengths, the SRCA should have a measurement uncertainty of 1.6 nm, allowing us to detect such shifts if they occur. Additionally, this is back in the direction of the fluorescence peak, and would be desirable. Therefore, the increase in shift sensitivity for the actual performance is not a concern.

As discussed with Band 13, the relative signal of Bands 13,14, and 15 is important for the FLH product. This will be discussed in a subsequent section.

Since the shift sensitivity is not a concern, the edge range does not extend the spectral response into any strong solar spectra, the SNR is still adequate, and the impact on the FLH product is minimal (see subsequent section), I believe that the center wavelength and lower edge range deviations are acceptable.

Band 15

Band 15 is an ocean band used to make atmospheric corrections of observations from other ocean bands and used in conjunction with Bands 13 and 14 to measure chlorophyll fluorescence. Figure 14 shows the nominal and expected system level performance of Band 15 imposed on a top-of-atmosphere spectrum over the ocean derived from MCST models. Figure 15 superimposes these responses against the solar spectrum and Figure 16 superimposes these responses against the surface exitance spectra used with Bands 13 and 14. Table 4 summarizes Band 15's characteristics.

For Band 15, SBRC has requested a deviation waiver for an edge range of 5.3 nm, which is 0.3 nm beyond specification. The convolved results indicate that the upper edge range is 5.3 nm (0.3 nm beyond specification) and the lower edge range is 5.1 nm (0.1 nm beyond specification). Figures 14 and 15 show that Band 15 does not encroach on the Fraunhofer line at 760 nm. SNR remains high. The integrated radiances given in Table 4 show that there is very little difference in the total normalized transmittance between the nominal and expected cases. As can be seen in Figures 14, 15 and 16, essentially the large edge ranges serve only to widen the extended bandpass slightly.

Figure 17 presents the shift sensitivity against the TOA spectrum. Since this includes the dominant solar line at 760 nm, we decided there was no need to do the shifting against the solar spectrum as well. Figure 17 shows that the expected performance is less sensitive to center wavelength shifts than the nominal filter.

Figure 18 shows the shift sensitivity against the ocean surface 10 mg/m^3 spectrum used with Bands 13 and 14. It indicates that the expected performance is better than the nominal performance for positive shifts and only slightly worse for negative shifts. Overall, Figures 17 and 18 indicate no significant increase in shift sensitivity for the expected performance compared to the nominal performance.

Band 15 is part of the chlorophyll product and is discussed in the chlorophyll fluorescence section.

Since the deviation in Edge Ranges does not affect the total signal, does not bring the band into dominant Fraunhofer lines, the expected performance is actually less sensitive to center wavelength shifts, and the impact on the FLH product is minimal (see subsequent section), I believe that it is acceptable.

Band 18

Band 18 was analyzed as part of the Band 19 Center Wavelength study (ref. 2). The data available to GSFC then showed an upper edge range of 6.7 nm. The current data indicates an upper edge range of 6.9 nm, which nudges the edge range from slightly within to slightly outside of specification (6.8 nm). This variation is less than the measurement uncertainty and does not affect any of the conclusions of reference 2. The deviation for the Upper Edge Range is therefore acceptable.

Band 19

There are no measurable differences between the as-built data and the data used in reference 2. That reference concluded with concurrence from Yoram Kaufman, that the center wavelength deviation, seen in Wafer 117, of -5 nm (2.6 nm beyond tolerance) was acceptable.

Chlorophyll Fluorescence

The primary Level 2 product affected by shifts in center wavelength in Bands 13, 14, and 15 is the Chlorophyll Fluorescence Product. As defined by Mark Abbott (ref. 6), one of the primary parameters is fluorescence line height (FLH). This is calculated as:

$$FLH = L_{14} - [(L_{13} - L_{15}) (\lambda_{14} - \lambda_{13}) / (\lambda_{13} - \lambda_{15}) + L_{13}] \qquad (1)$$

where L_x is the calibrated radiance in band x and λ_y is the center wavelength at band y. For waiver purposes, I have assumed ideal calibration and atmospheric correction. The radiance values can then be taken as the integrated in-band radiance over the ocean surface spectra. I used the two ocean spectra (10 mg/m^3 and 0.01 mg/m^3 of Chlorophyll) shown previously in figures 6, 10 and 16. Table 5 summarizes the calculation of the FLH. As can be seen, the difference for the 10 mg spectrum is less than 1%. The 0.01 spectrum results will be discussed in a subsequent paragraph.

Additionally, with the MCST tools, it is relatively easy to determine the shift sensitivity of the FLH product. Figure 19 presents the shift sensitivity of the FLH product, assuming all three bands shift together (other permutations were not calculated due to time considerations). This is a reasonable approximation because the filters are made of similar materials and are closely located on the focal plane (in fact, the filters for Bands 14 and 15 share a common substrate). Figure 19 shows that the expected performance closely follows the nominal performance (slightly worse for negative shifts and slightly better for positive shifts). The shifting results indicate minimal impact on the FLH product from the deviations in the actual performance.

Besides examining the 10 mg/m^3 chlorophyll spectrum, I have examined the FLH product as it would be measured over the 0.01 mg/m^3 spectrum. This is problematic, because the 0.01 mg/m^3 spectrum is essentially the flat ocean background with no fluorescence line. Abbott's ATBD (in equation 1 above) explicitly assumes that the background may be approximated by a straight line. Figure 20, where the scale has been expanded, shows that this background is not exactly flat.

The effects of the small variations in the 0.01 mg/m^3 spectrum are minor in the Level 1 products. Figure 21 presents the shift sensitivity for all bands. As can be seen, the shifts are nearly flat straight lines, as would be the case for a linear background, except for Band 15, which is susceptible to the structure in the oceans spectrum at 720 nm and 760 nm. However, these small variations in the 0.01 spectrum can have significant effects on the Level 2 FLH product. Since the FLH product is the height above a straight line, for this spectrum it is possible for the fluctuations to drop below the straight line and result in a negative FLH. Figure 22 shows how this is possible. Figure 23 plots values of the FLH for the 0.01 mg/m^3 spectrum, where again Bands 13, 14, and 15 are assumed to have all shifted equally. As can be seen, for some cases, the FLH is negative. These values are also changing dramatically, resulting in the 73% variation between the nominal performance FLH and the expected performance FLH given in Table 5.

I believe that these variations are a representation of the "noise" floor or uncertainty in the algorithm and not the result of the differences in the nominal and expected band performances. These values are three orders of magnitude smaller than those determined for the 10 mg/m^3 spectrum (Table 5). The effects are dominated by the small structure in the spectrum, which is taken by Abbott to be flat. As such, I believe that the deviations in the actual performance of the filters do not significantly affect the FLH product for the 0.01 mg/m^3 spectrum. Combined with the results from the 10 mg/m^3 spectrum, I believe that the deviations in Bands 13, 14, and 15 have a minimal impact on the chlorophyll fluorescence product.

Conclusion

My analysis indicates that the deviations given above do not significantly affect the Level 1B product or the Level 2 Fluorescence Line Height Product. The shift sensitivity results indicate that small future shifts in center wavelength will not significantly affect either product and large shifts both are not expected (given the SeaWiFS experience with ion-impact filters similar to those used for MODIS) and are detectable (with the SRCA).

Based on the analysis above, I recommend accepting the deviations summarized in Table 6 on the following page.

Edward J. Knight

Edward J. Knight/RDC/MCST Optical Engineer

cc:
Paul Anuta/RDC
Phil Ardanuy/RDC
Bruce Guenther/925
Robert Mahoney/RPS
Harry Montgomery/925

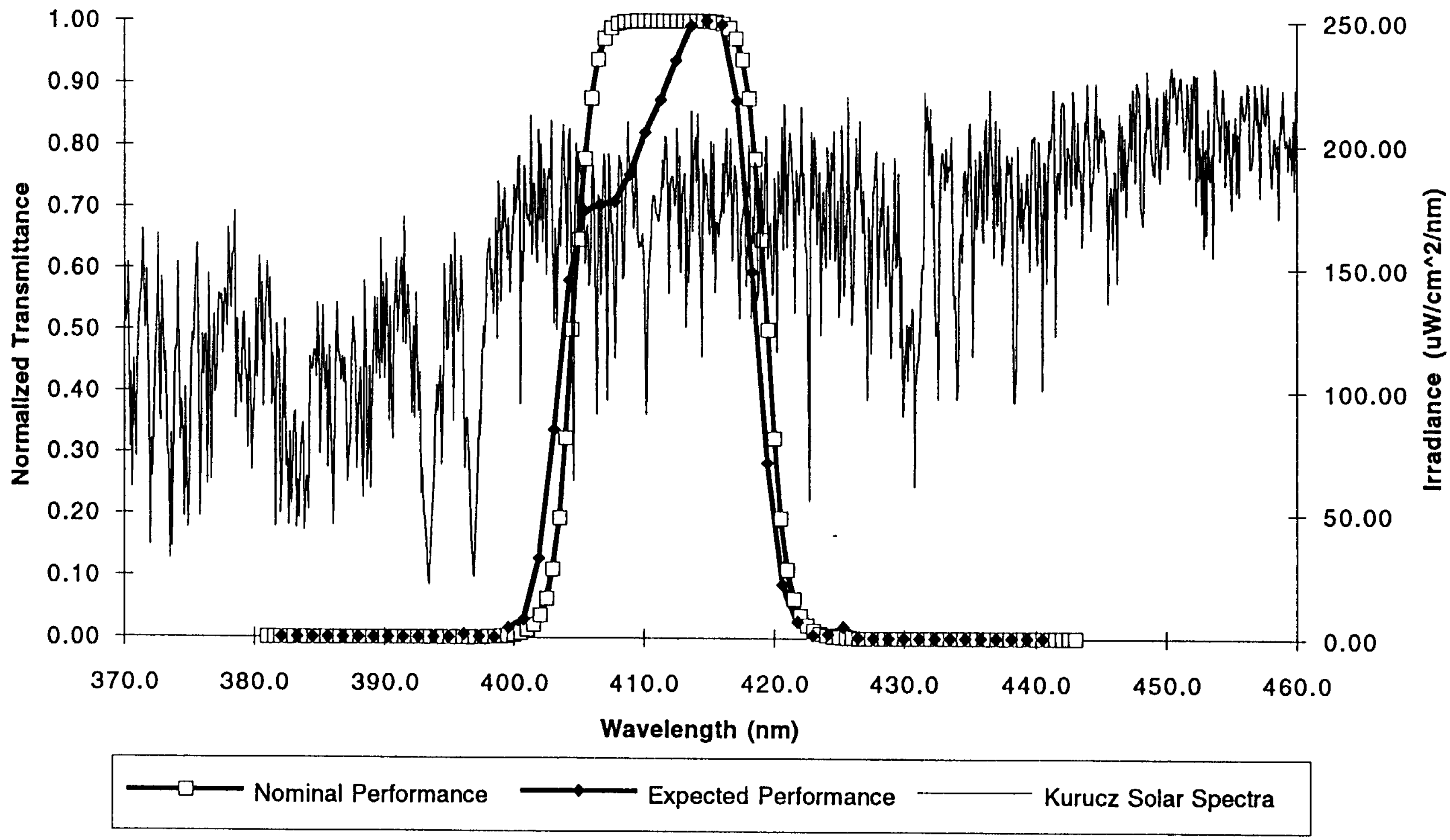
TABLE 6

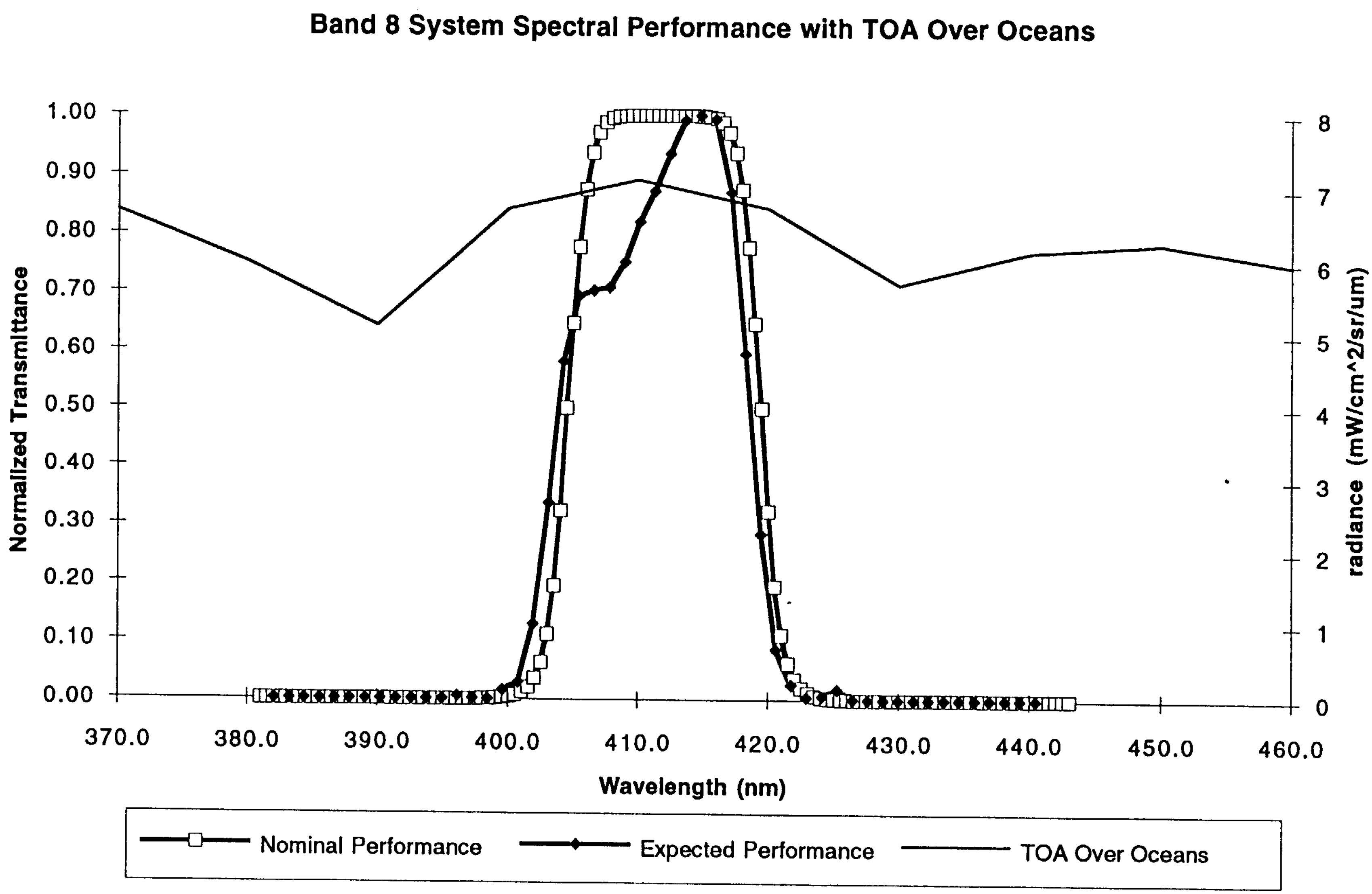
RECOMMENDED ACCEPTABLE DEVIATIONS

Band	Parameter	Spec. Value (nm)	Request (nm)	Recommended Acceptance (nm)
14	Center Wavelength	678±1.0	678±1.3	676.7
19	Center Wavelength	940±2.4	940±5.0	935
11	Bandwidth	10±1.9	10±2.0	12
8	Edge Range	7.4	8.8	LER 8.8
9	Edge Range	5.5	7.3	LER 7.3 UER 6.8
13	Edge Range	5.05	6.1	UER 6.1
14	Edge Range	5.7	5.8	LER 5.8
15	Edge Range	5.0	5.3	LER 5.1 UER 5.3
18	Edge Range	6.8	6.9	UER 6.9

(UER=Upper Edge Range, LER=Lower Edge Range)

Band 8 System Spectral Performance with Kurucz Solar Spectra





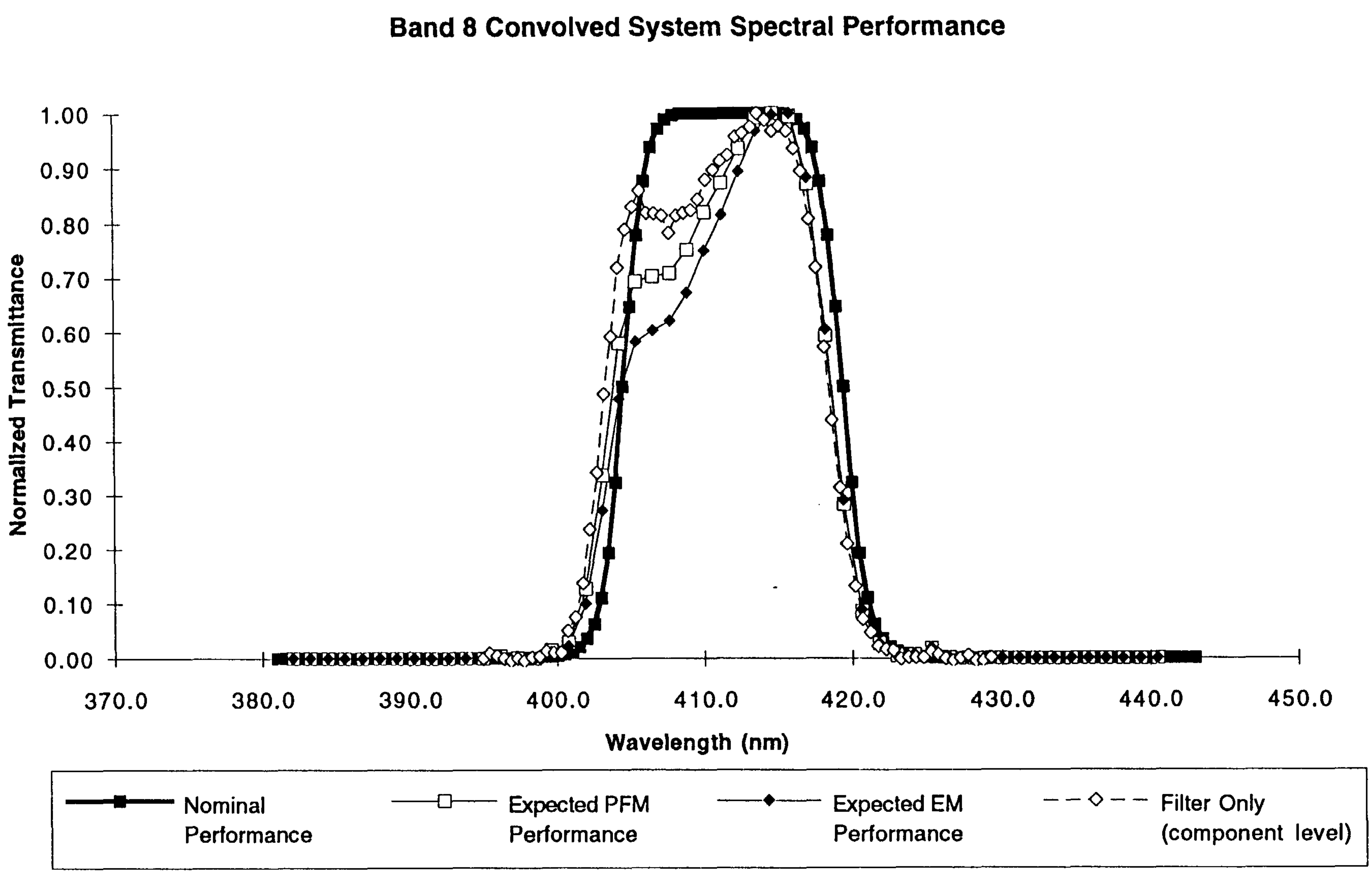
MCST/Knight

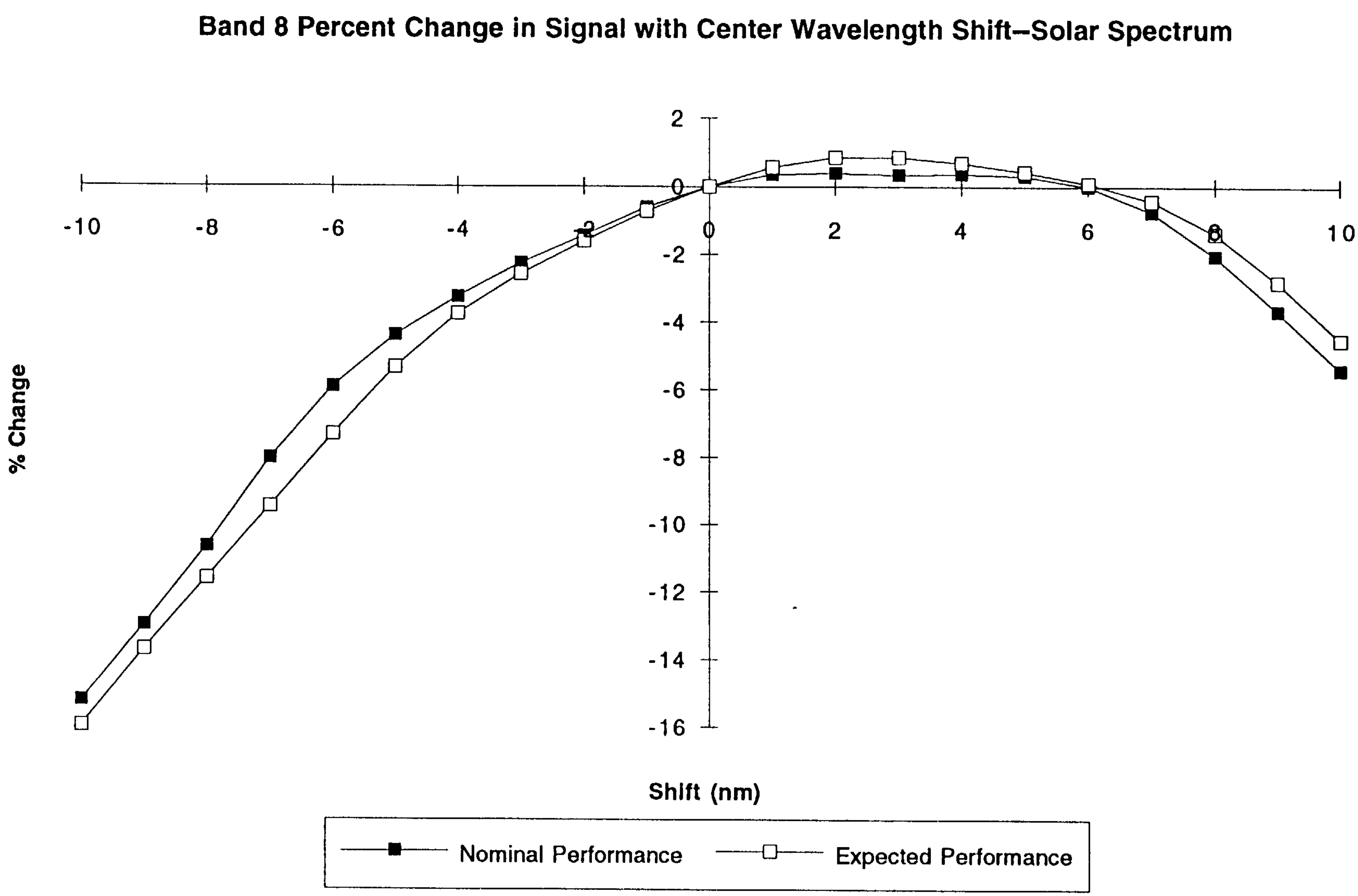
FIGURE 2

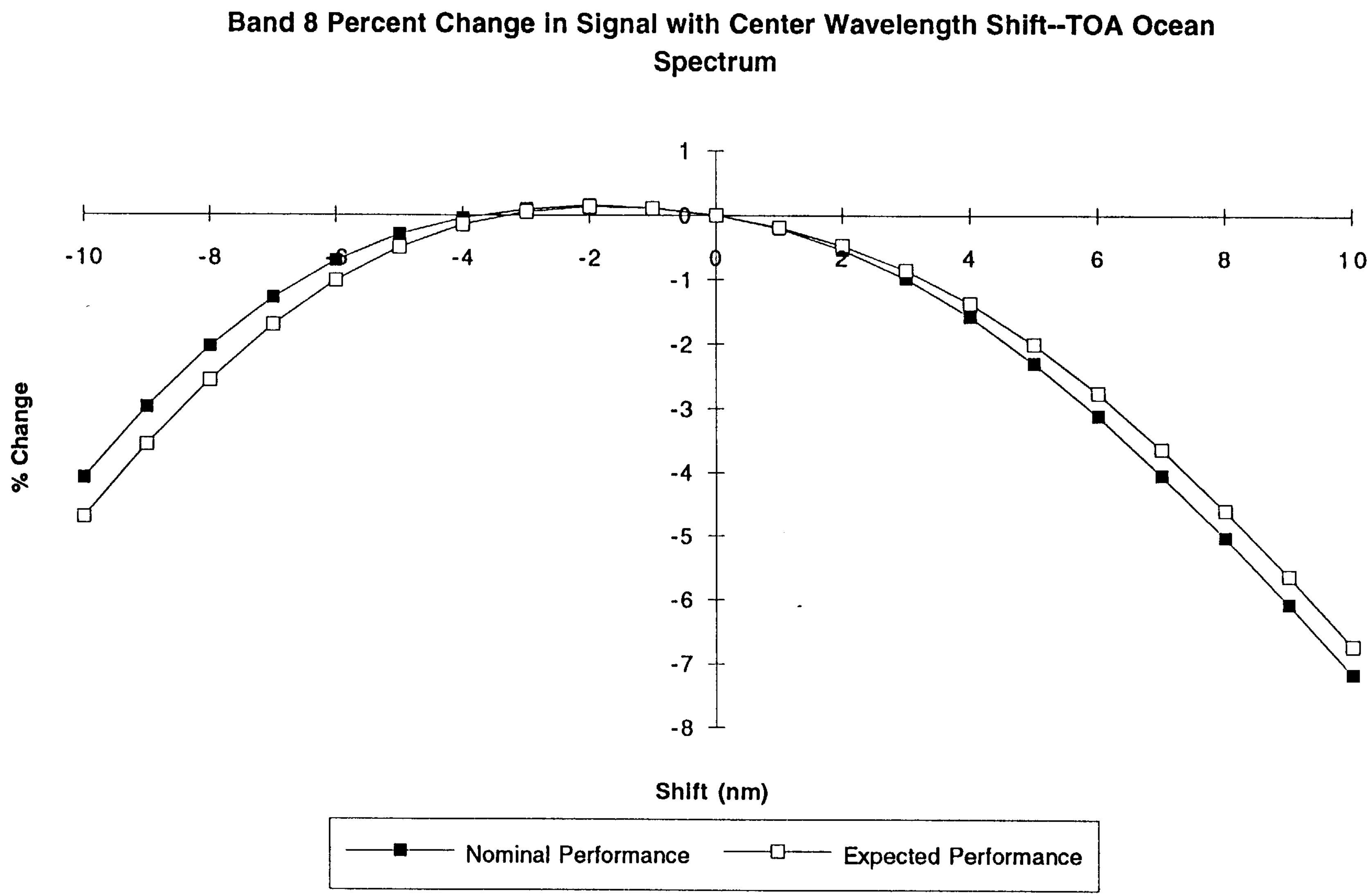
11/10/94 B8 Plots Chart 2

TABLE 1

FILTER RESULTS					
Band 08					
	Specification	Tolerance	sys.Data 11/94		
			PFM	EM	
CW band 8	412.0	+/- 2.0	411.3	411.6	nm
BW band 8	15.0	+/- 1.5	14.8	14.2	nm
LER band 8		< 0.5*BW	8.8	9.8	nm
UER band 8		< 0.5*BW	3.9	3.9	nm
ripple band 8	none		none	none	
1%pts band 8	<	ICW +/- 2*BWI	in spec.	in spec.	
SNR Band 8	880		1102		
Definitions					
CW=Center Wavelength		wavelength of midpoint between 50% (peak t) points			
BW=Band Width		distance between 50% points			
LER=Lower Edge Range		distance from 5%-80% points on lower wavelength side			
UER=Upper Edge Range		distance from 80%-5% points on upper wavelength side			
ripple		all points between 80% pts must be above 80%			
1% pts		1% points must fall within 2*BW from the CW			
SNR		Signal to Noise Ratio			
Integrated Radiances					
integration over extended bandpass (between 1% pts) of the normalized transmittance					
This provides a measure of the expected signal seen					
t*nm				Unnormalized	
Int. Range		Int. Range		Int. Range	
Nom.	Nominal Filter	Sys.Data (PF)	Sys.Data (PF)	Sys.Data (PF)	Sys. Data (PF)
401.0-423.5	14.95	400.1-423.0	13.31	400.1-423.0	4.81
nm		nm		nm	

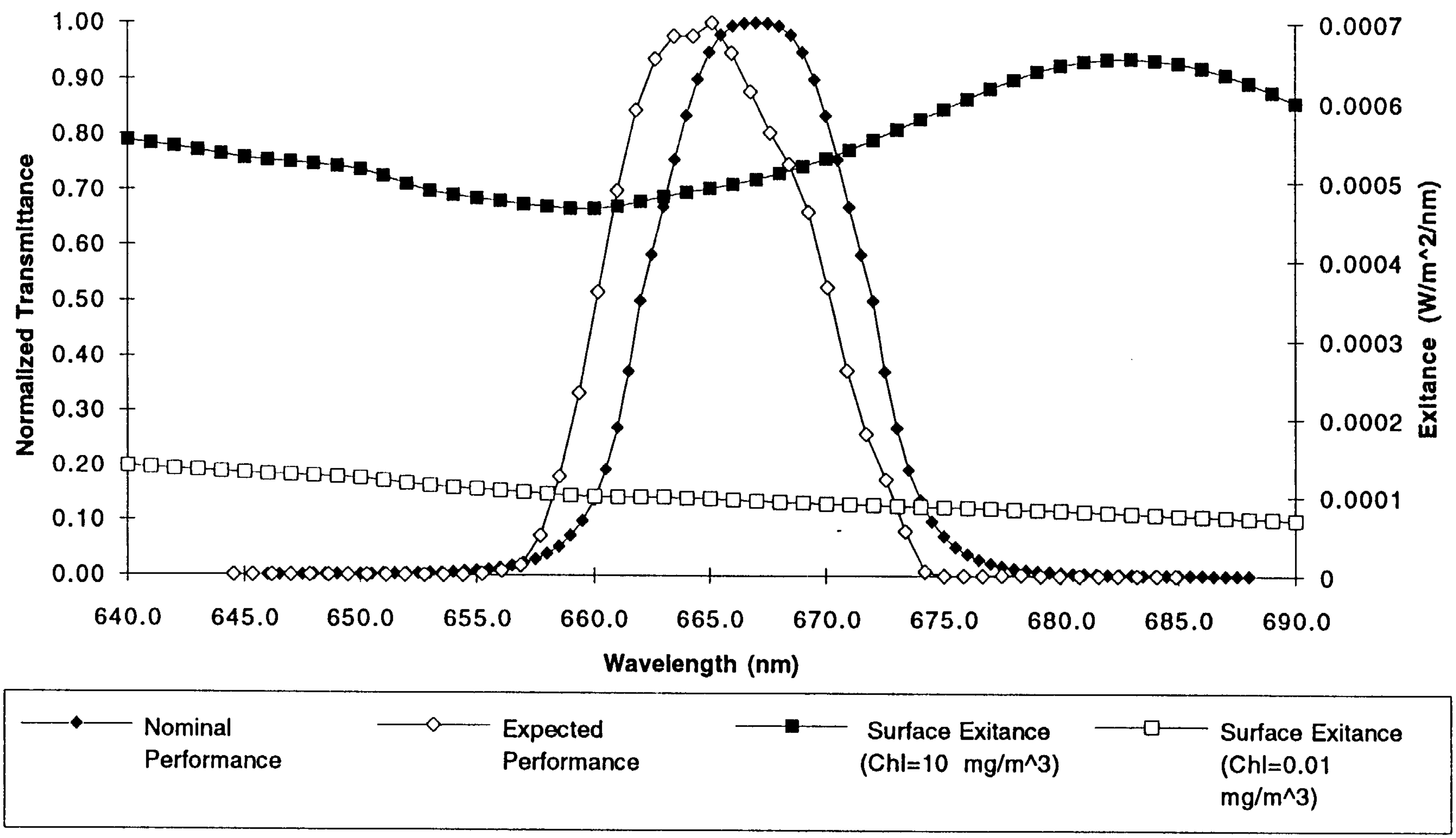

Band 8 Convolved System Spectral Performance
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Normalized Transmittance
370.0
380.0
390.0
400.0
410.0
420.0
430.0
440.0
450.0
Wavelength (nm)
Nominal Performance
Expected PFM Performance
Expected EM Performance
Filter Only (component level)


Band 8 Percent Change in Signal with Center Wavelength Shift--Solar Spectrum
% Change
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-10
-8
-6
-4
-2
0
2
4
6
8
10
Shift (nm)
Nominal Performance
Expected Performance



Band 8 Percent Change in Signal with Center Wavelength Shift--TOA Ocean Spectrum
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-10
-8
-6
-4
-2
0
2
4
6
8
10
% Change
Shift (nm)
Nominal Performance
Expected Performance

Band 13 with Ocean Surface Exitance for different Chlorophyll levels



Band 13 with Kurucz Solar Spectra

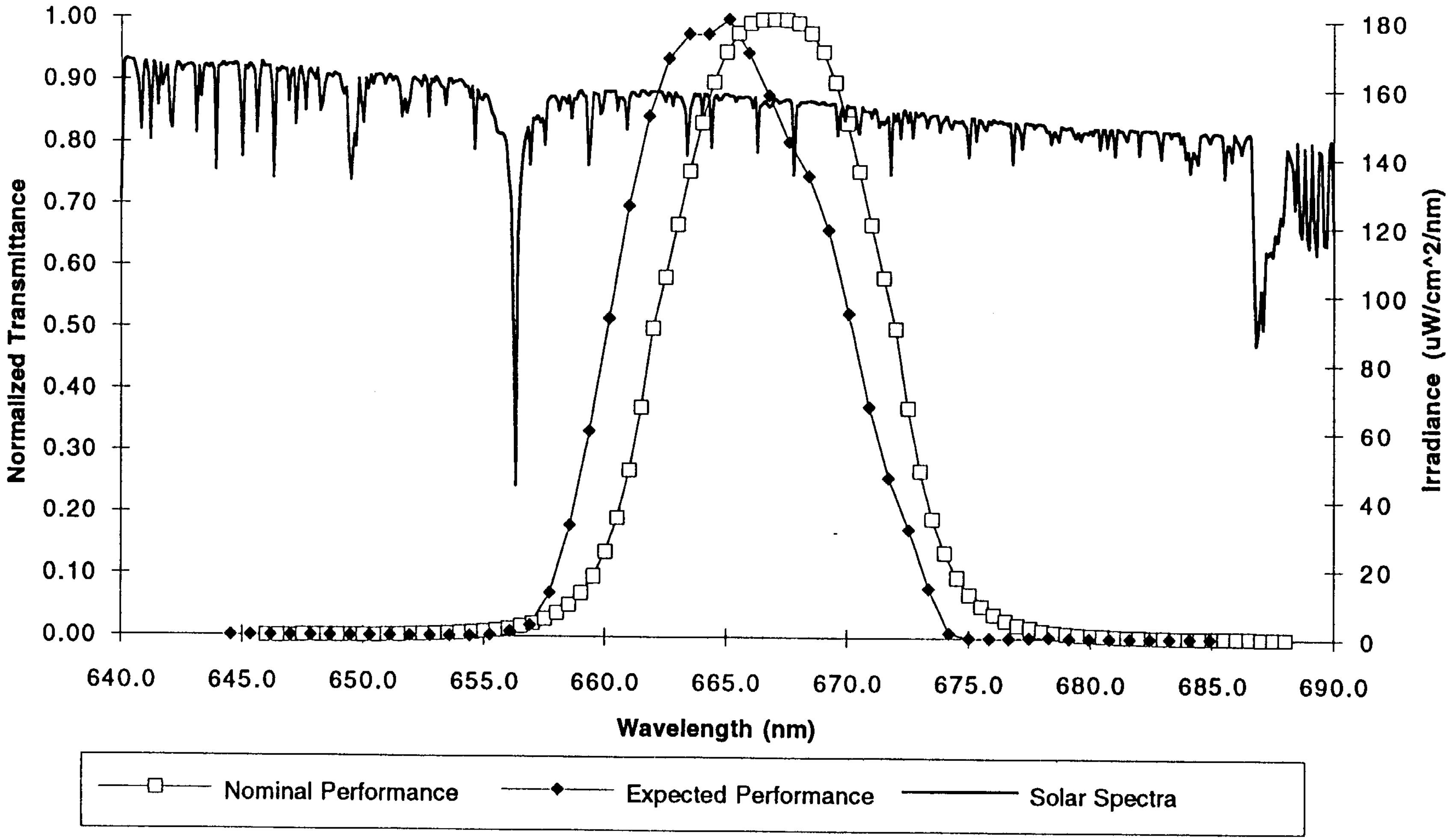
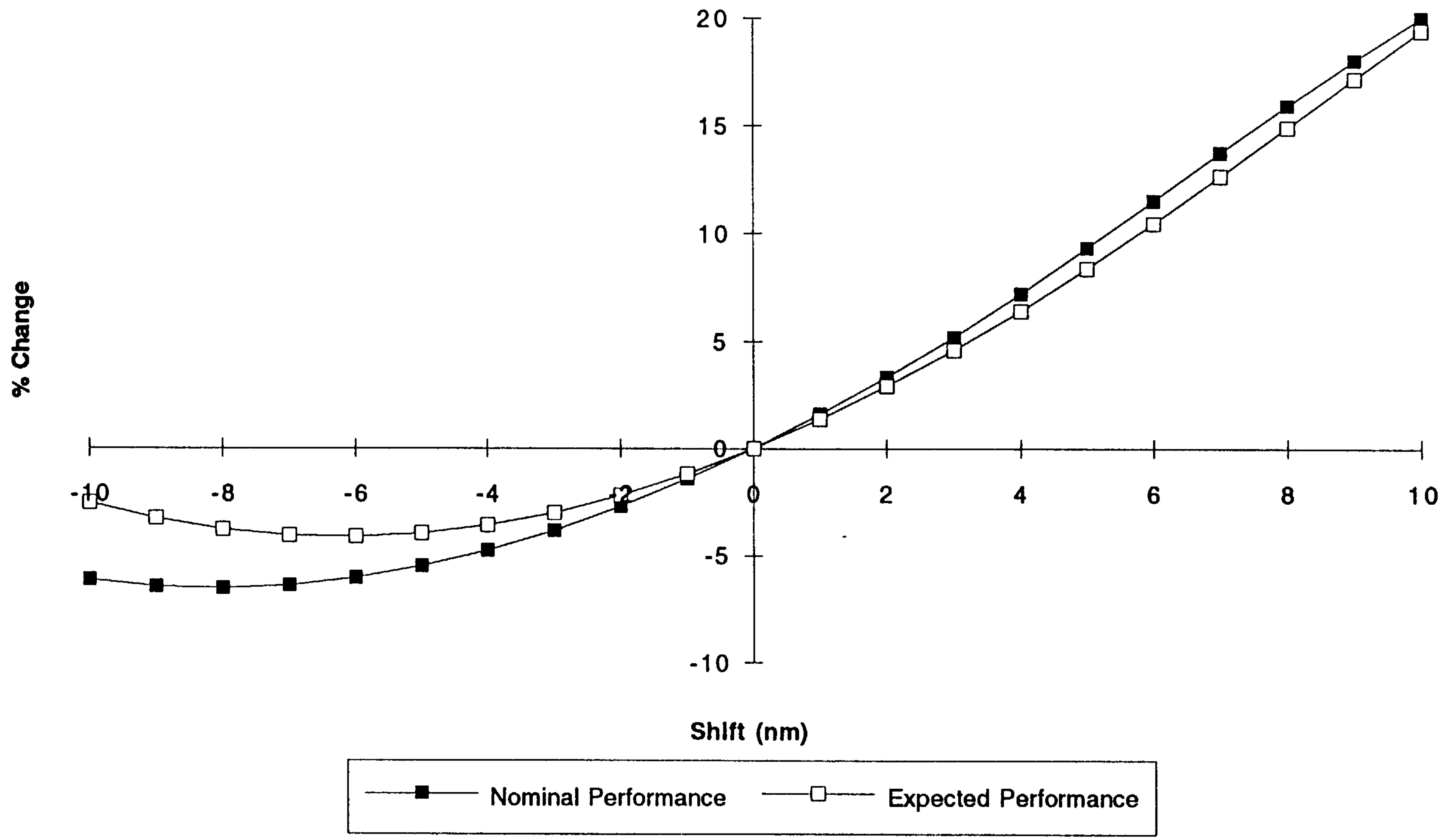


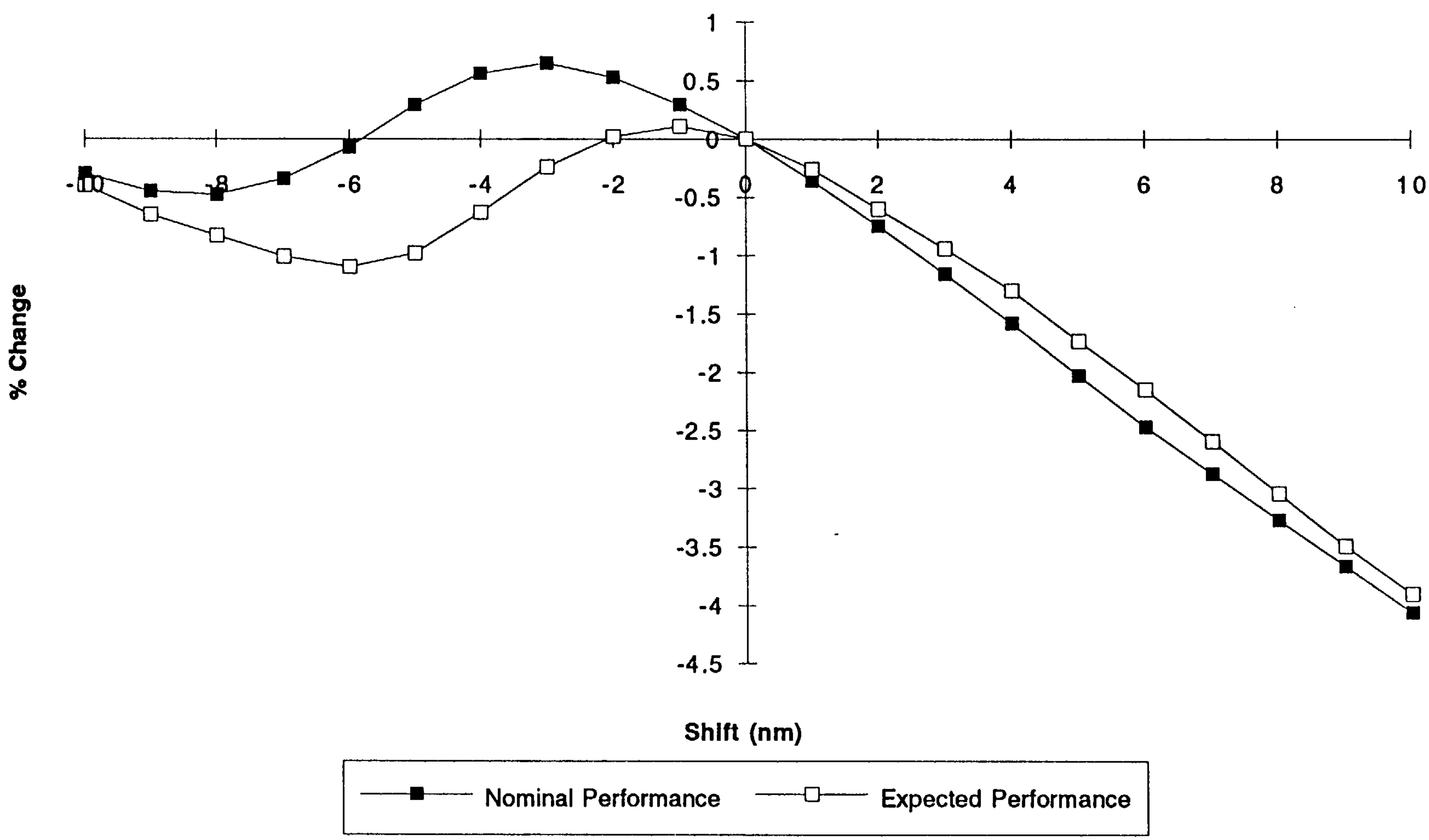
TABLE 2

FILTER RESULTS					
Band 13					
	Specification	Tolerance	sys.Data 10/94		
CW band 13	667.0	+1,-2	665.2	nm	
BW band 13	10.0	+/- 1.7	10.1	nm	
LER band 13		< 0.5*BW	4.2	nm	
UER band 13		< 0.5*BW	6.1	nm	
ripple band 13	none		none		
1%pts band 13	<	ICW +/- 2*BWI	in spec.		
SNR Band 13	910		1368		
Definitions					
CW=Center Wavelength		wavelength of midpoint between 50% (peak t) points			
BW=Band Width		distance between 50% points			
LER=Lower Edge Range		distance from 5%-80% points on lower wavelength side			
UER=Upper Edge Range		distance from 80%-5% points on upper wavelength side			
ripple		all points between 80% pts must be above 80%			
1% pts		1% points must fall within 2*BW from the CW			
SNR		Signal to Noise Ratio			
Integrated Radiances					
integration over extended bandpass (between 1% pts) of the normalized transmittance					
This provides a measure of the expected signal seen					
t*nm				Unnormalized	
Int. Range		Int. Range		Int. Range	
Nom.	Nominal Filter	Sys.Data	Sys.Data	Sys.Data	Sys. Data
655.5-679.0	9.98	656.1-674.2	9.89	656.1-674.2	3.32
nm		nm		nm	

Band 13 Percent Change in Signal with Center Wavelength Shift--Oceans Spectrum



Band 13 Percent Change in Signal with Center Wavelength Shift--Solar Spectrum



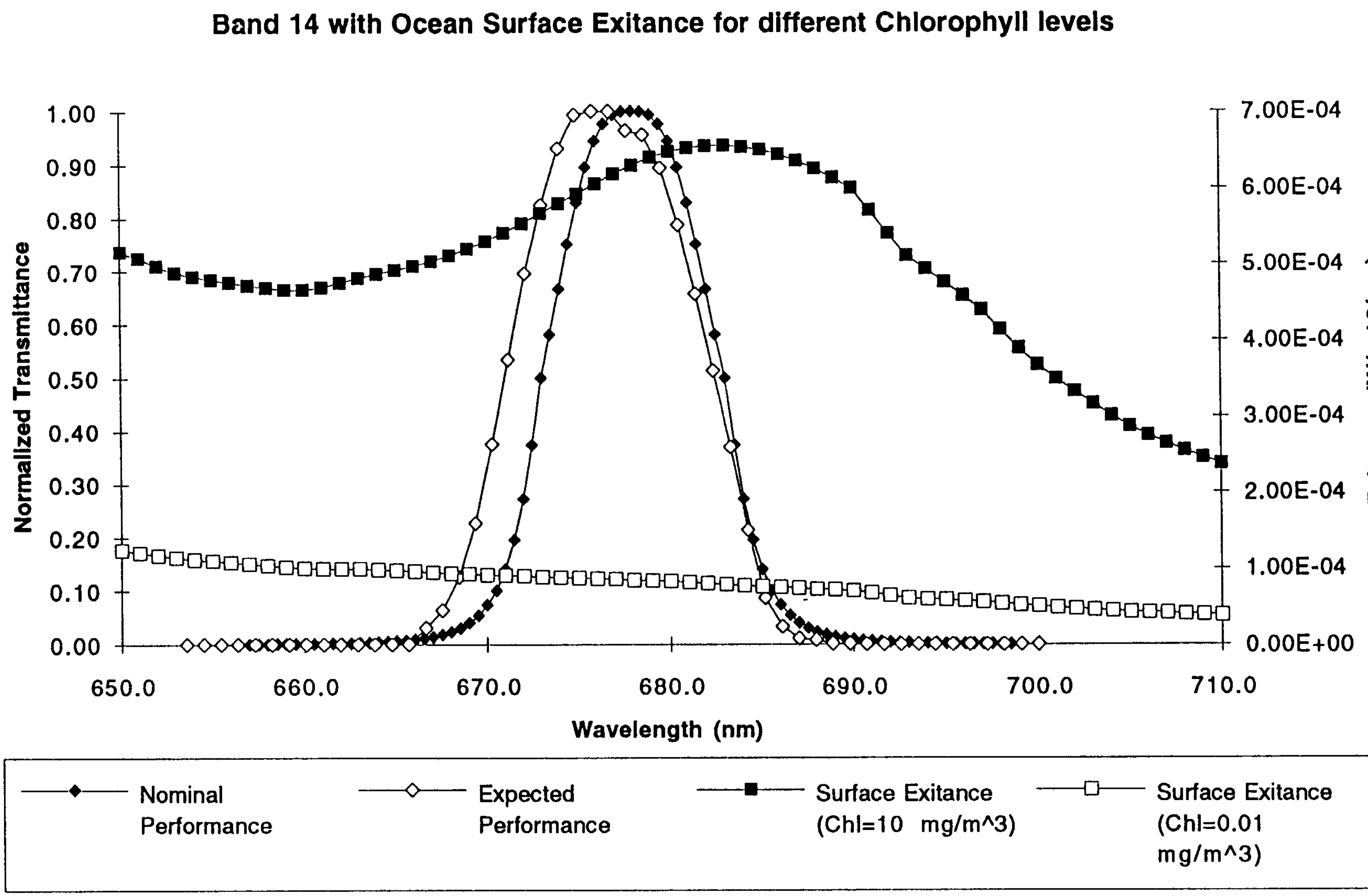
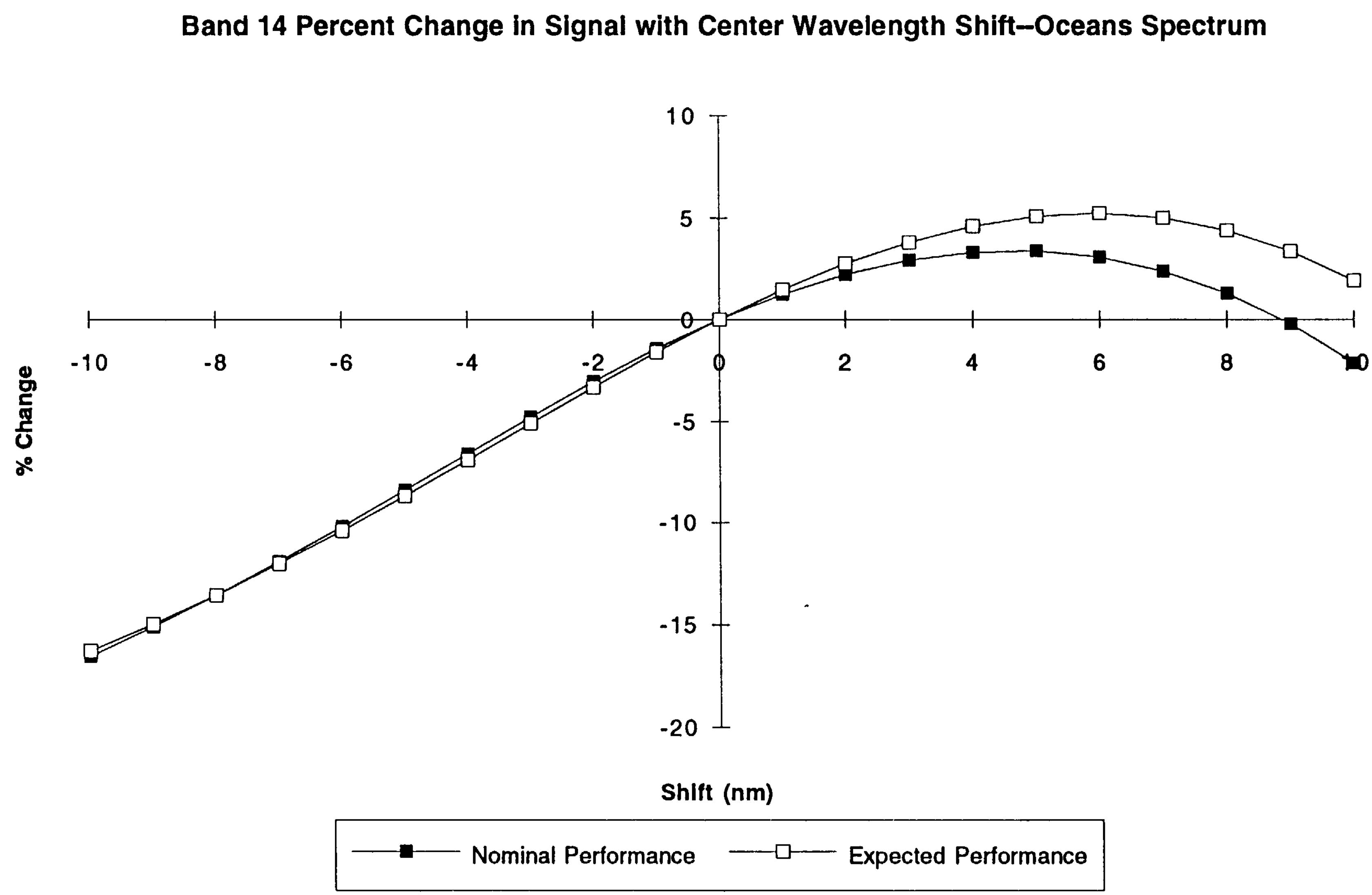

Band 14 with Ocean Surface Exitance for different Chlorophyll levels
Normalized Transmittance
Exitance (W/m^2/nm)
Wavelength (nm)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E+00
650.0
660.0
670.0
680.0
690.0
700.0
710.0
Nominal Performance
Expected Performance
Surface Exitance (Chl=10 mg/m^3)
Surface Exitance (Chl=0.01 mg/m^3)

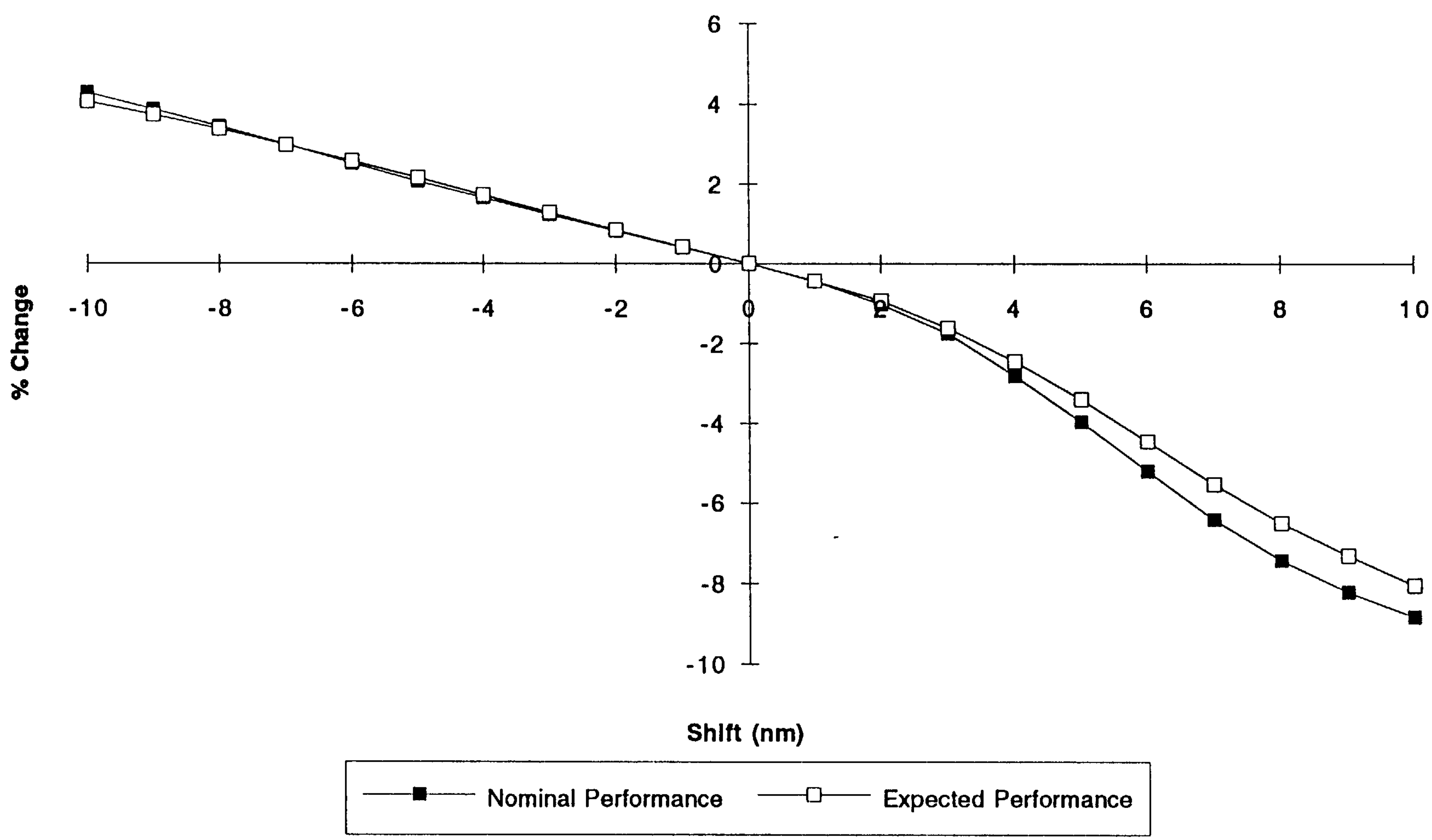
TABLE 3

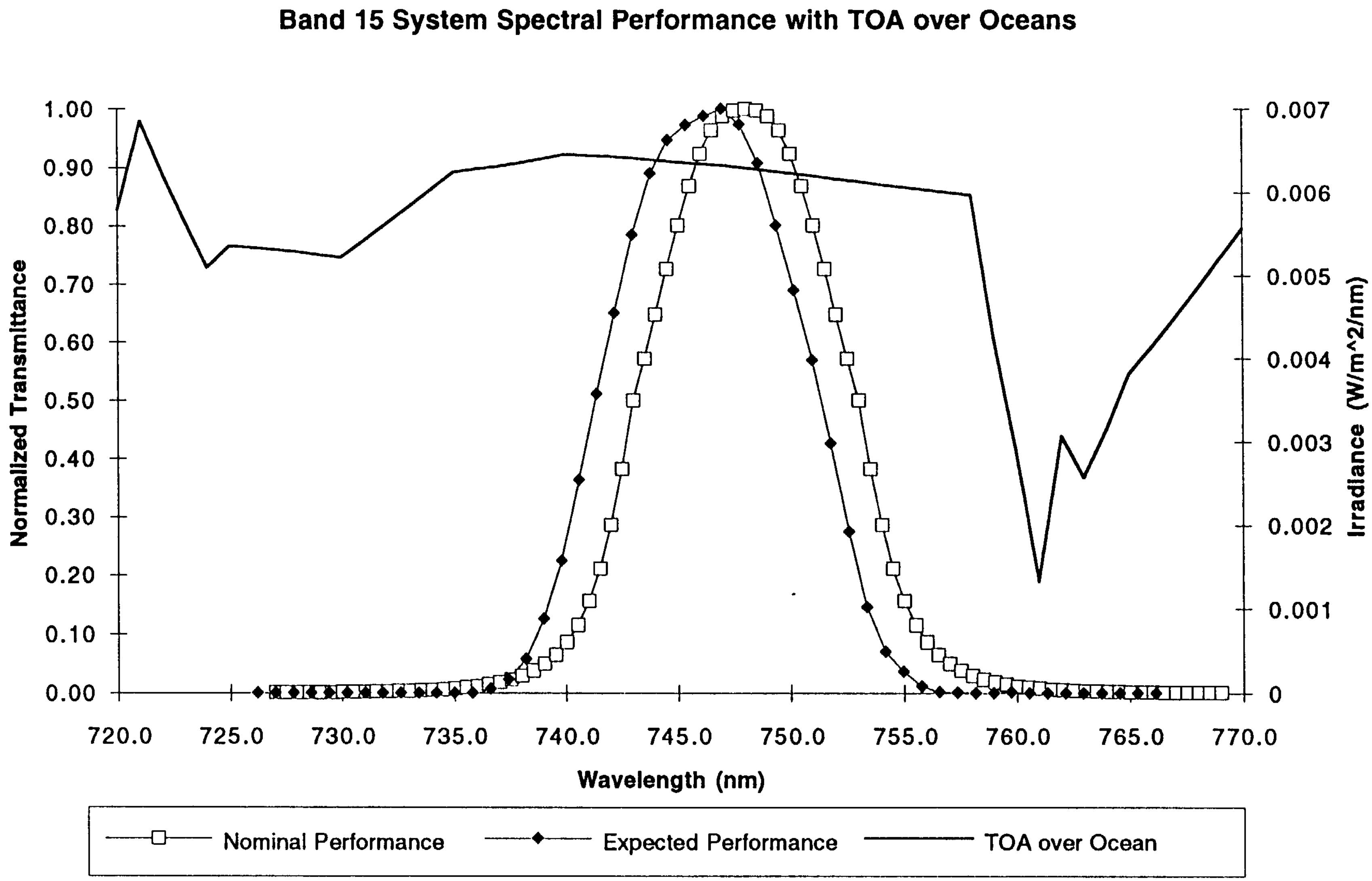
FILTER RESULTS					
Band 14					
	Specification	Tolerance	sys.Data 10/94		
CW band 14	678.0	+/- 1.0	676.7	nm	
BW band 14	10.0	+/- 1.7	11.4	nm	
LER band 14		< 0.5*BW	5.8	nm	
UER band 14		< 0.5*BW	5.4	nm	
ripple band 14	none		none		
1%pts band 14	<	ICW +/- 2*BWI	unknown		
SNR Band 14	1087		1683.0		
Definitions					
CW=Center Wavelength		wavelength of midpoint between 50% (peak t) points			
BW=Band Width		distance between 50% points			
LER=Lower Edge Range		distance from 5%-80% points on lower wavelength side			
UER=Upper Edge Range		distance from 80%-5% points on upper wavelength side			
ripple		all points between 80% pts must be above 80%			
1% pts		1% points must fall within 2*BW from the CW			
SNR		Signal to Noise Ratio			
Integrated Radiances					
integration over extended bandpass (between 1% pts) of the normalized transmittance					
(over all available data for actual performance)					
This provides a measure of the expected signal seen					
t*nm				Unnormalized	
Int. Range		Int. Range		Int. Range	
Nom.	Nominal Filter	Sys.Data	Sys.Data	Sys.Data	Sys. Data
666.5-690.0	9.98	665.7-687.9	11.41	665.7-687.9	5.26
nm		nm		nm	



Band 14 Percent Change in Signal with Center Wavelength Shift--Oceans Spectrum
10
5
0
-5
-10
-15
-20
-10
-8
-6
-4
-2
0
2
4
6
8
10
% Change
Shift (nm)
Nominal Performance
Expected Performance

Band 14 Percent Change in Signal with Center Wavelength Shift--Solar Spectrum





Band 15 System Spectral Performance with TOA over Oceans
Normalized Transmittance
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Irradiance (W/m^2/nm)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
720.0
725.0
730.0
735.0
740.0
745.0
750.0
755.0
760.0
765.0
770.0
Wavelength (nm)
Nominal Performance
Expected Performance
TOA over Ocean

Band 15 System Spectral Performance with Kurucz Solar Spectra

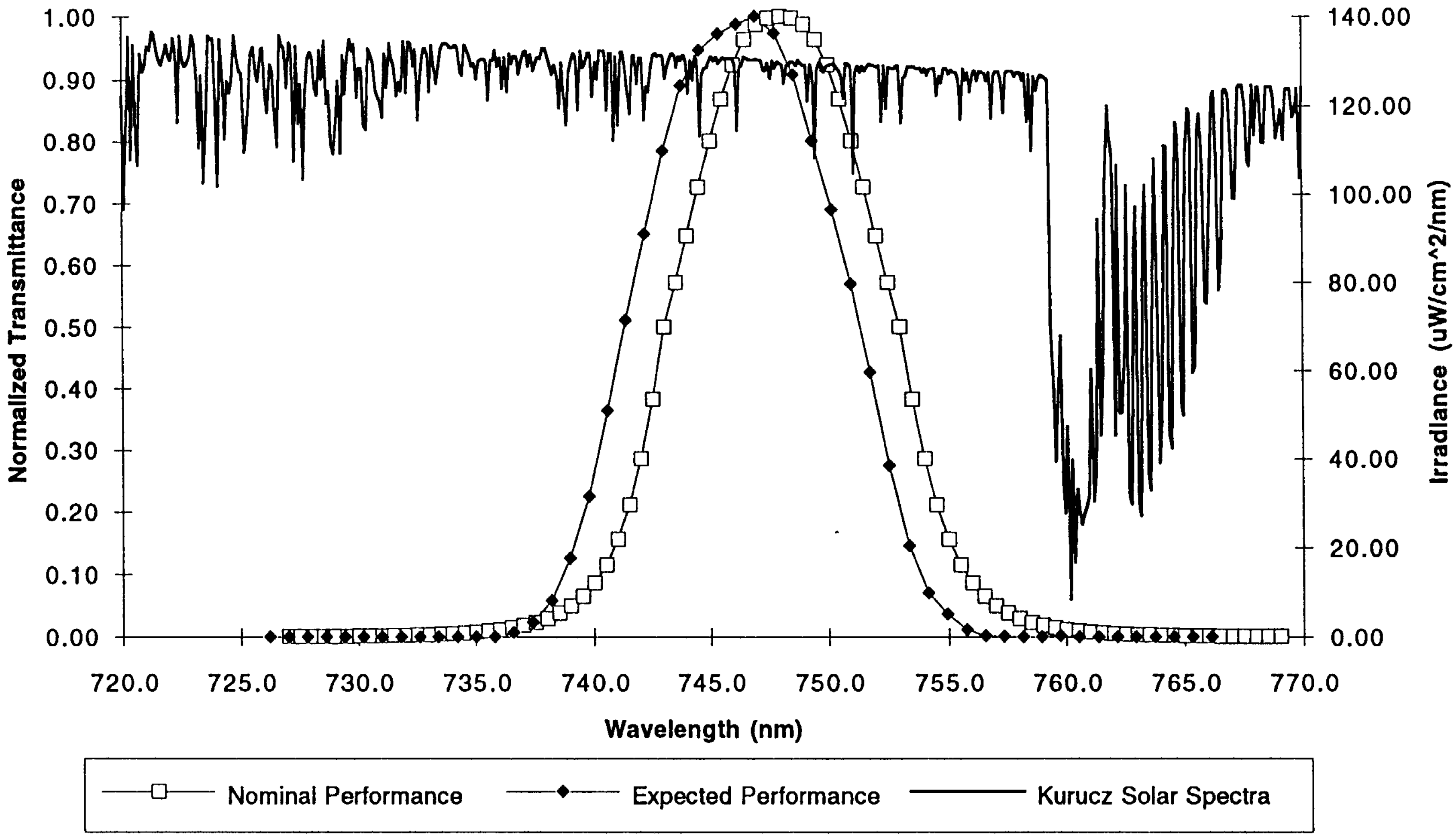
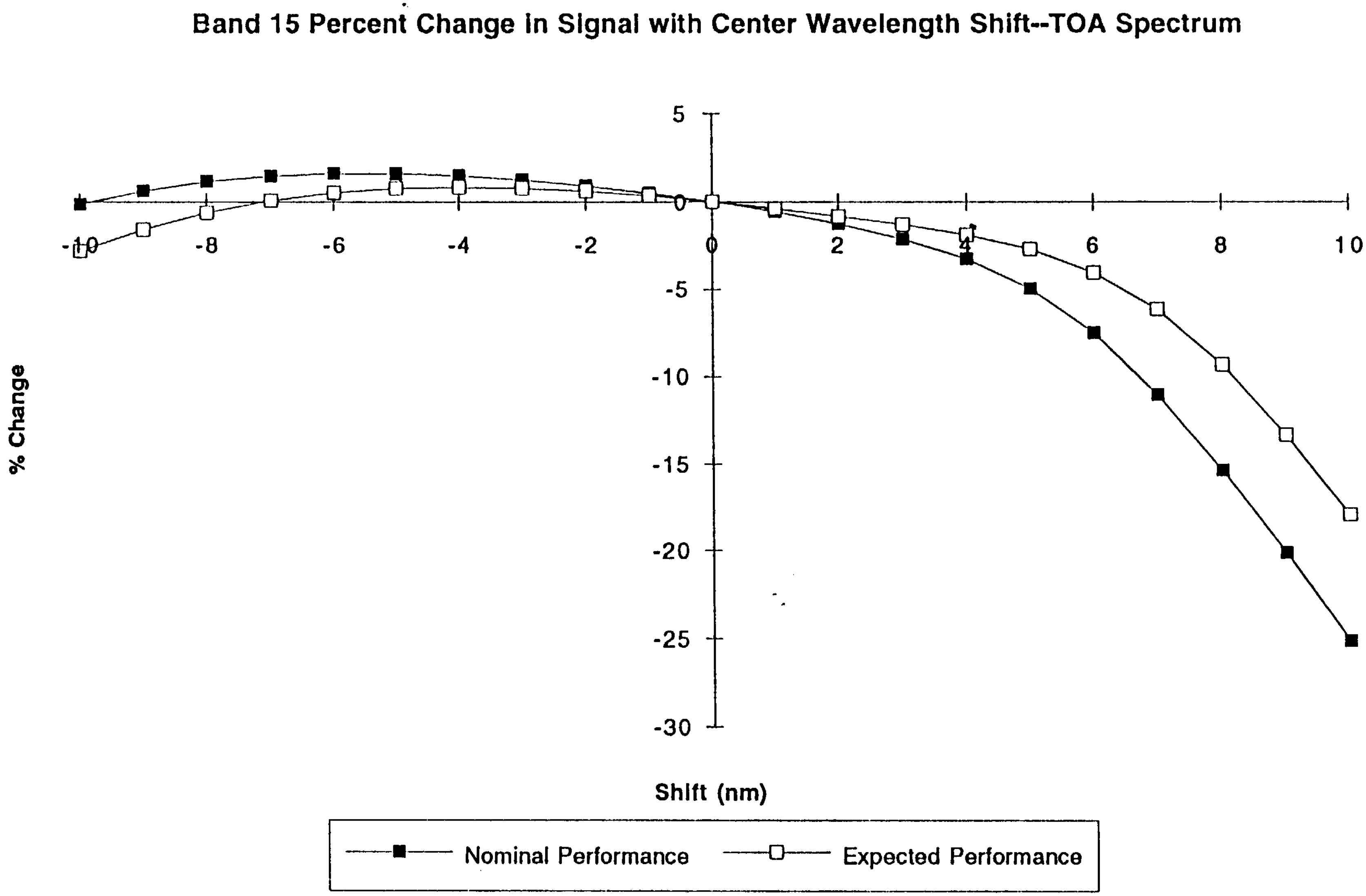


TABLE 4

FILTER RESULTS					
Band 15					
	Specification	Tolerance	sys.Data 11/94		
CW band 15	748.0	+/- 2.0	746.3	nm	
BW band 15	10.0	+/- 1.9	10.0	nm	
LER band 15		< 0.5*BW	5.1	nm	
UER band 15		< 0.5*BW	5.3	nm	
ripple band 15	none		none		
1%pts band 15	<	ICW +/- 2*BWI	in spec.		
SNR Band 15	586		1290		
Definitions					
CW=Center Wavelength		wavelength of midpoint between 50% (peak t) points			
BW=Band Width		distance between 50% points			
LER=Lower Edge Range		distance from 5%-80% points on lower wavelength side			
UER=Upper Edge Range		distance from 80%-5% points on upper wavelength side			
ripple		all points between 80% pts must be above 80%			
1% pts		1% points must fall within 2*BW from the CW			
SNR		Signal to Noise Ratio			
Integrated Radiances					
integration over extended bandpass (between 1% pts) of the normalized transmittance					
This provides a measure of the expected signal seen					
t*nm				Unnormalized	
Int. Range		Int. Range		Int. Range	
Nom.	Nominal Filter	Sys.Data	Sys.Data	Sys.Data	Sys. Data
735.5-760.5	9.98	736.6-755.7	9.93	736.6-755.7	5.33
nm		nm		nm	



MCST/Knight

FIGURE 17

11/10/94 shifting.visnirplots Chart 1

Band 15 Percent Change in Signal with Center Wavelength Shift–Oceans Surface Spectrum

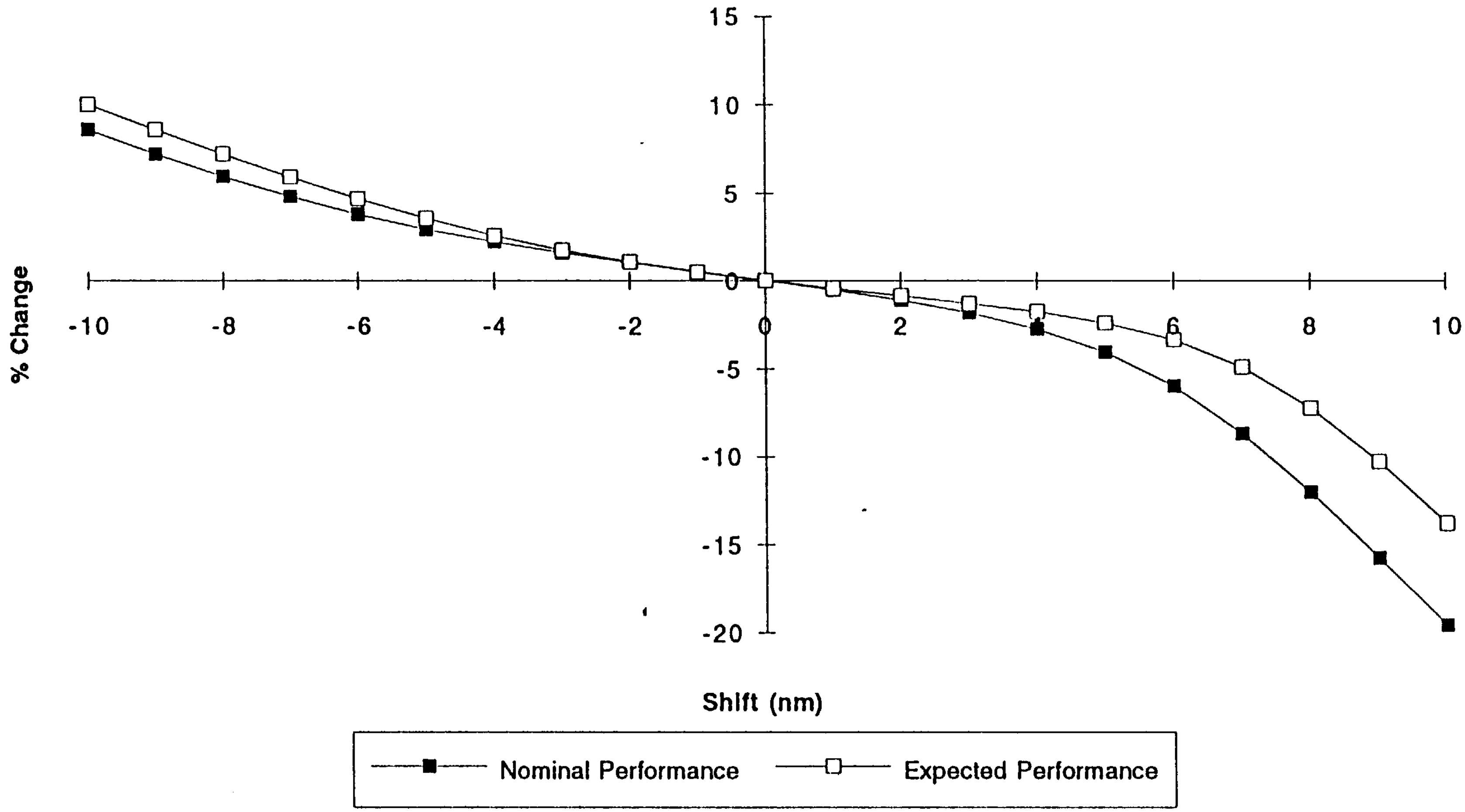
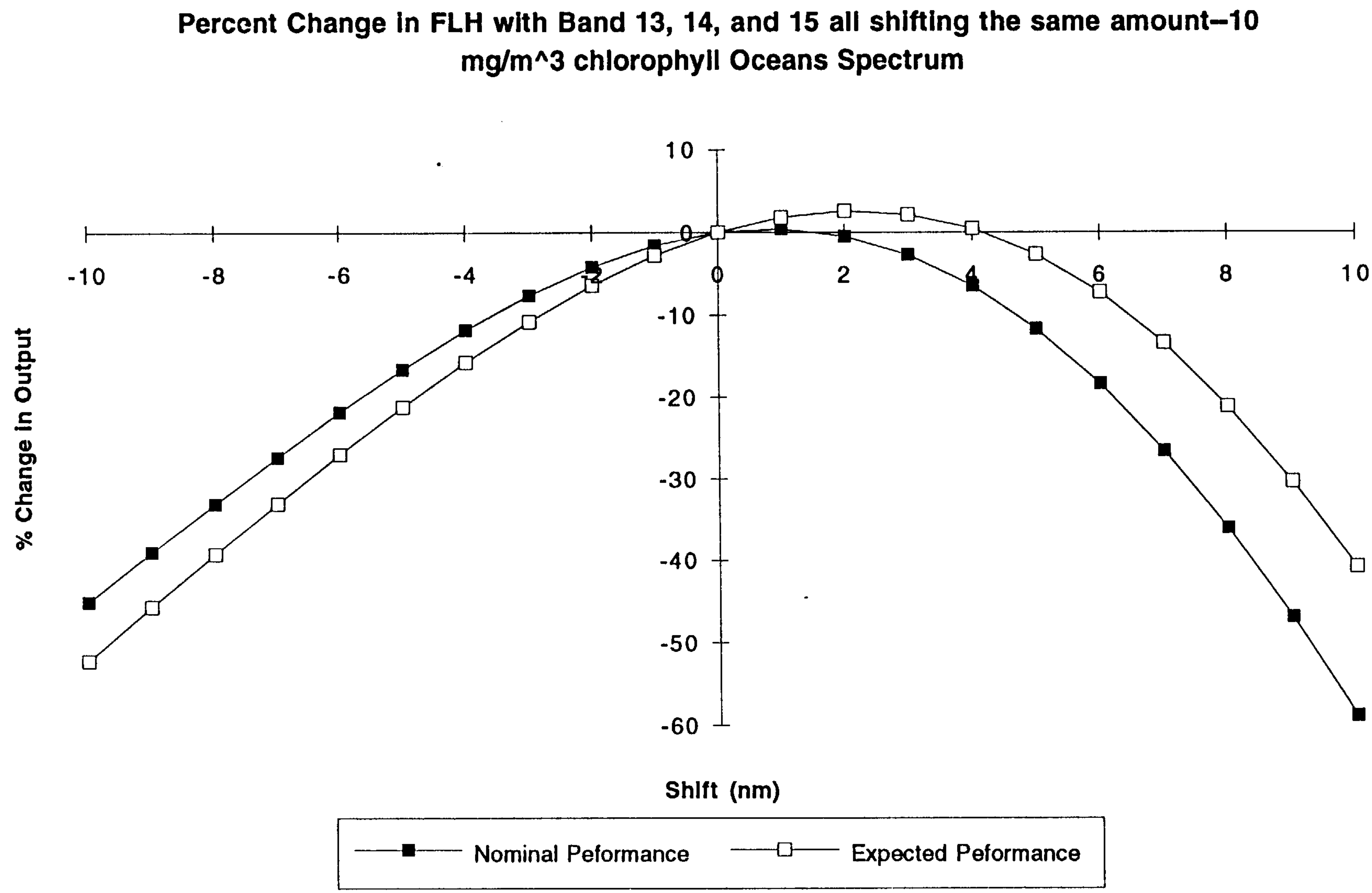
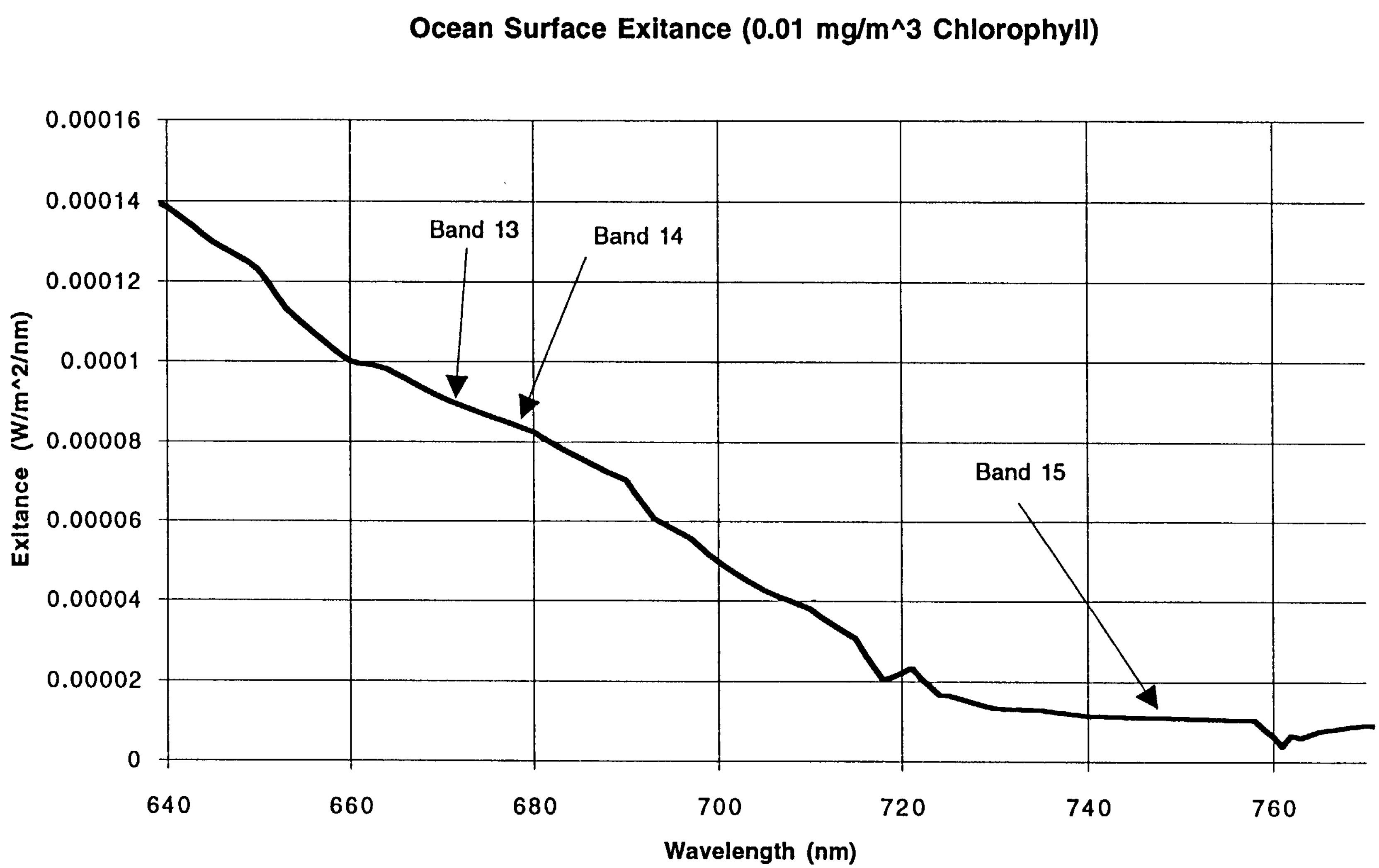


TABLE 5

Chlorophyll Fluorescence					
VISNIR Filter Deviation Waiver Study					
		Normalized	Normalized		
		Nominal	Expected		
		Performance	Performance		
CW Band 13		667	665.2		nm
CW Band 14		678	676.7		nm
CW Band 15		748	746.3		nm
Int.R 10 Band 13		0.00050931	0.00049639		W/m^2/nm
Int.R 10 Band 14		0.0006188	0.00060664		W/m^2/nm
Int.R 10 Band 15		7.1851E-05	7.2485E-05		W/m^2/nm
Int.R 0.01 Band 13		9.4264E-05	9.599E-05		W/m^2/nm
Int.R 0.01 Band 14		8.3503E-05	8.4901E-05		W/m^2/nm
Int.R 0.01 Band 15		1.0938E-05	1.1009E-05		W/m^2/nm
FLH 10		0.0001689	0.00017036		W/m^2/nm
FLH 0.01		5.5455E-07	9.6098E-07		W/m^2/nm
% Difference FLH 10:		0.86370271			
% Difference FLH 0.01:		73.2893131			
CW=Center Wavelength		wavelength of midpoint between 50% (peak t) points			
Int.R 10=Integrated Radiance of spectral response convolved with 10 mg/m^3 Ocean					
	Surface Spectra				
Int.R 0.01=Integrated Radiance of spectral response convolved with 0.01 mg/m^3 Ocean					
	Surface Spectra				
FLH 10=Fluorescence Line Height 10 mg.m^3 Ocean Spectra					
FLH 0.01=Fluorescence Line Height 0.01 mg.m^3 Ocean Spectra					
%Difference = (exp-nom)/exp *100					
Normalized so that integration over spectral response alone = 1					

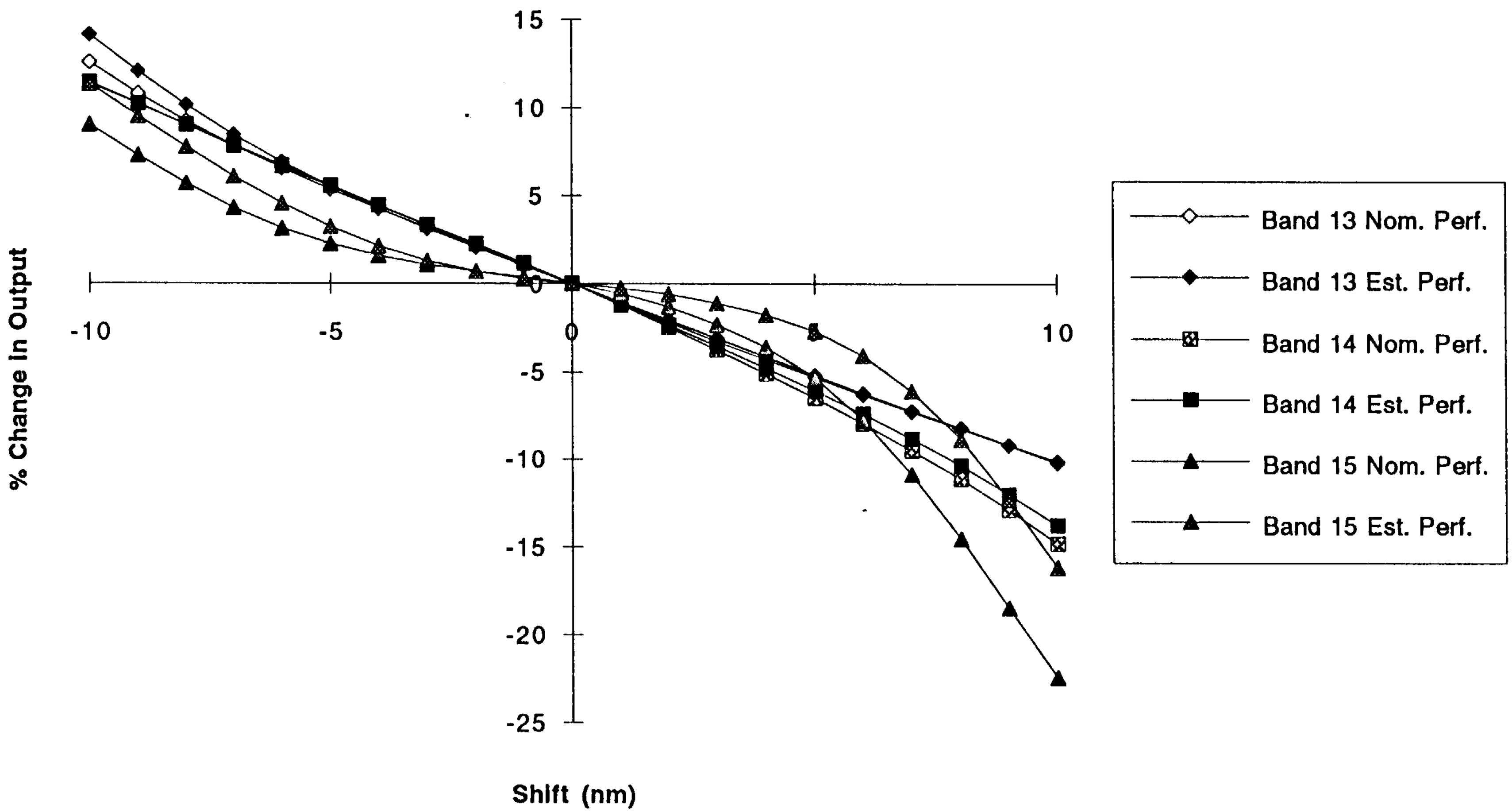


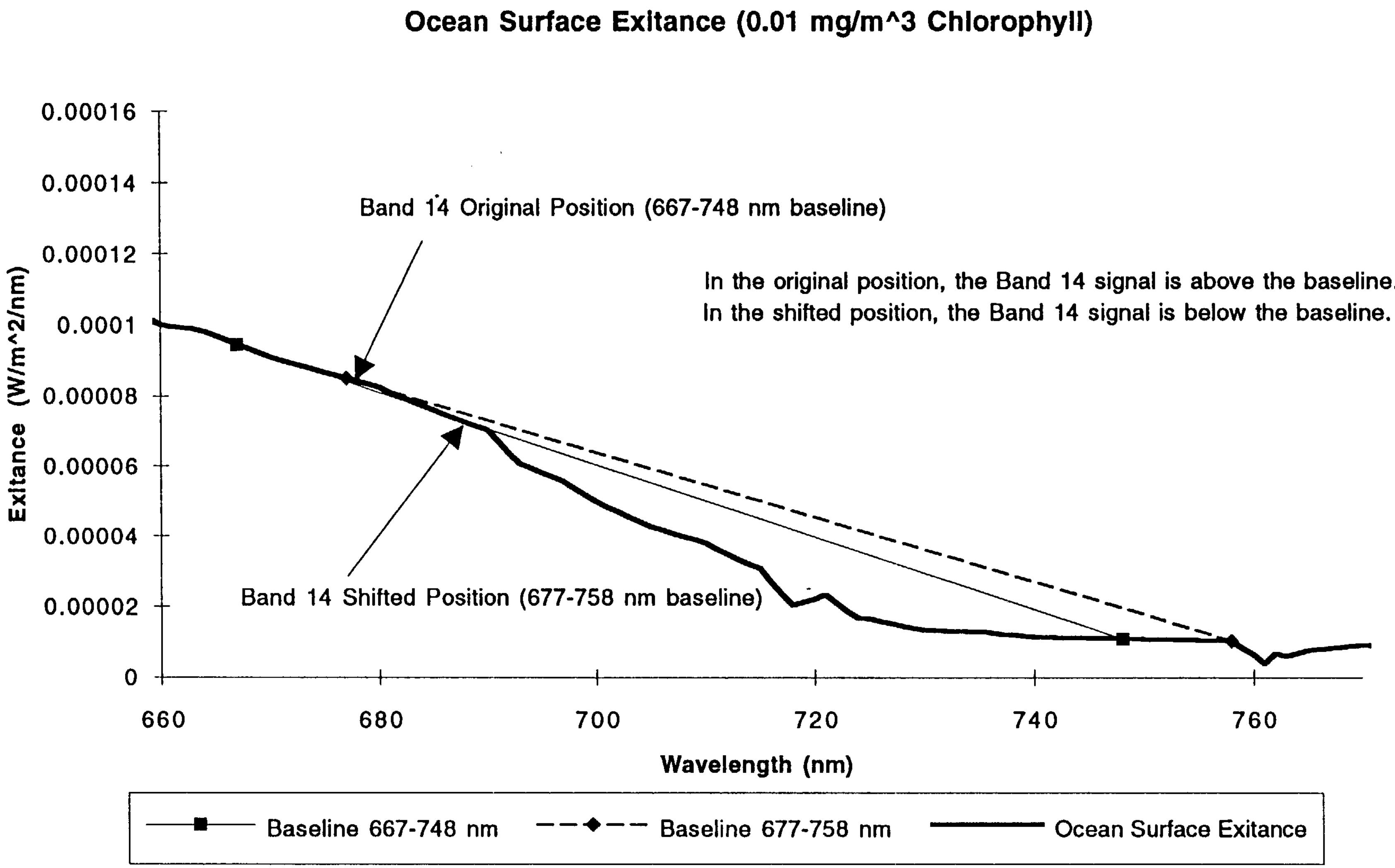
Percent Change in FLH with Band 13, 14, and 15 all shifting the same amount--10 mg/m^3 chlorophyll Oceans Spectrum
10
0
-10
-20
-30
-40
-50
-60
-10
-8
-6
-4
-2
0
2
4
6
8
10
% Change in Output
Shift (nm)
Nominal Peformance
Expected Peformance



Ocean Surface Exitance (0.01 mg/m^3 Chlorophyll)
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
Exitance (W/m^2/nm)
Band 13
Band 14
Band 15
640
660
680
700
720
740
760
Wavelength (nm)

Bands 13, 14, and 15 Percent Change in Signal with Center Wavelength Shift--0.01 mg/m^3 chlorophyll Oceans Spectrum




Ocean Surface Exitance (0.01 mg/m^3 Chlorophyll)
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
Exitance (W/m^2/nm)
Band 14 Original Position (667-748 nm baseline)
In the original position, the Band 14 signal is above the baseline.
In the shifted position, the Band 14 signal is below the baseline.
Band 14 Shifted Position (677-758 nm baseline)
660
680
700
720
740
760
Wavelength (nm)
Baseline 667-748 nm
Baseline 677-758 nm
Ocean Surface Exitance

Fluorescence Line Height over 0.01 mg/m^3 Ocean Exitance Spectrum as a function of Center Wavelength shift in Bands 13, 14, and 15 (all shifting the same)